SPACEFLIGHT MICROFABRICATED SCANNING ELECTRON MICROSCOPE AND X-RAY SPECTROMETER (MSEMS). DAVID BLAKE[1], CATTIEN V. NGUYEN[2], BRYAN P. RIBAYA[2,3], DARREL NIEMANN[2,3], MAHMUD RAHMAN[3], GEETHA R. DHOLAKIA[2], ADNAN AALAM[2], VINH NGO[2], CHRIS MCKENZIE[4], DAVID JOY[5], and BOB ESPINOSA[4], [1]MS 239-4, NASA Ames Research Center, Moffett Field, CA 94035 (dblake@mail.arc.nasa.gov),[2]MS 229-1, NASA Ames Research Center, Moffett Field, CA 94035, [3]Department of Electrical Engineering, Santa Clara University, Santa Clara, CA [4]InXitu, Inc., Mountain View, CA, [5]Oakridge National Laboratory, Oakridge, TN

Introduction: One of the most powerful techniques for the characterization of natural samples is Scanning Electron Microscopy combined with electron-induced X-ray Fluorescence Spectroscopy (SEM-EDX). Natural processes that can be elucidated with SEM-EDX include low-temperature diagenesis, thermal or pressure induced metamorphism, volcanism/magmatism, atmosphere/crust interaction and the like. This information is useful in elucidating the natural history of solar system objects such as Phobos and Deimos, and in providing a spatial and temporal context for other concurrent measurements such as isotopic analysis or radiometric dating.

The MSEMS Instrument: The MSEMS will incorporate a novel cathode technology utilizing a carbon nanotube field emitter (CNTFE). The use of a CNTFE cathode is advantageous from the standpoint of low power usage, ultrasmall source size and simplicity of the electrostatic focusing and scanning elements. The electron source, electron optical column and sample stage assembly of the prototype MSEMS instrument are envisioned to be 1-2 cm in height. MSEMS will operate in the range 500 eV - 15 KeV and will be used to demonstrate the feasibility of a miniaturized but highly capable SEM-EDX instrument, and its relevance to planetary science.

Progress to Date: MSEMS technology development is being pursued concurrently in three areas: Electron source, MEMS electron column and Sample Stage. A key feature of the design is that the electron gun and MEMS column are fixed-focus, having a stationary electron beam; Gross sample movement, scanning and focusing are accomplished with a precision 3-axis piezo-driven stage.

Carbon nanotube electron source. Two features of the emitted electron beam that are necessary for high-resolution electron microscopy are low energy spread and high brightness, both of which are improved in an individual CNT in comparison to conventional electron sources. Energy spreads as low as 0.2 eV have been reported for a single CNT emitter. Brightness values of $1\text{-}3\times10^9$ A sr^{-1} m^{-2} V^{-1} have been achieved for carbon nanotube emitters. These values are more than an order of magnitude greater than those of other known electron emitters. We have demonstrated a fabrication technique utilizing a Si based cathode structure for a robust CNT emitter. A stable and reproducible emission current >100 nA from was achieved, more than suffient for the MSEMS application.

MEMS Electron Column. The nature of the CNT electron source, fabricated from a Si microstructure allows for complementary integration of micro-electro-mechanical-system (MEMS). The electron extractor is being fabricated using a metal coated Si_3N_4 membrane. The extraction aperture will be integrated with the CNT electron source and will serve as the base on which the electron optics will be fabricated using silicon based electrostatic lenses.

Piezoelectric Sample Stage. Emission current from the tip at the extractor will be used to regulate the height\alignment of the sample relative to the column. Scanning to create 2-D images will be performed through piezo X-Y sample stage movement rather than by beam deflection and rastering. Piezo-based movements driven by STM-like electronics typically allow scan ranges from a few angstroms to several hundreds of microns. This highly compact and lightweight design combined with its high resolution makes it an ideal tool for spaceflight instrumentation.

Conclusions: At the present time, landed *in-situ* imagery of rocks or soil has an ultimate spatial resolution of tens of microns (e.g., the “hand lens” camera aboard MER), and compositional data are obtained from surface areas of at least one cm diameter (e.g., the APXS aboard MER). MSEMS will offer an improvement of at least two orders of magintude in these measurements, yielding data at or below the scale length of the mineral phases or grains in soil, dust and rocks. Laboratory-quality high resolution imagery and elemental analysis are important to planetary science; with no sample return missions presently planned or approved, there will be no prospect of performing this level of resolution of imagery or analysis in terrestrial laboratories for the next 1-2 decades.

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